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Variability of Taste Perception[a]

DAVID R. PERYAM
Armed Forces Food & Container Institute, Chicago 9, Ill.

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SUMMARY

High inter-personal variability has been noted in the taste qualities people report for solutions of sodium benzoate. This study sought to determine whether such variability occurs with other substances and to assess the role of learning in development of the response. 24 *S*'s replicated ratings of the intensity of *sweet, salt, sour,* and *bitter* in solutions representing 3 concentrations each of 4 familiar and 4 unfamiliar substances. Significant interpersonal variability was found for all substances. It was lower for the familiar substances (sucrose, salt, citric acid, and caffein) than for the unfamiliar ones (sodium benzoate, monosodium glutamate, potassium chloride, ammonium chloride, and a "model" solution). Thus, learning appears to be important.

Sodium benzoate, during a period starting about 9 years ago, created a flurry of interest among those concerned with the sensory evaluation of foods. A. L. Fox (1954) suggested, on the basis of some extensive experimentation, that people's taste responses to this chemical could reliably classify them as *sweet, salt, sour, bitter,* or *tasteless* tasters. People grasped at this straw of information. Here was a bold new way to evaluate people and perhaps to select taste panels. However, interest gradually waned—in large part because no one was able to verify Fox's results (Hoover, 1956).

The Food & Container Institute conducted a series of experiments directed toward the effects of sodium benzoate itself. The results failed to confirm Fox *in toto*—in fact, they suggested that he was more wrong than right; however, they did verify his finding of high interpersonal variability in the qualities that people use to describe the taste of sodium benzoate (Peryam, 1960). Evidence against Fox's theory included: 1) there were important sources of variability other than inter-personal; 2) people typically responded with multiple rather than single qualities; and 3) they could not be classified reliably on the basis of their responses. It was conjectured that much of the variation was probably related to differences among people in learning and language, and, if so, that it would not be unique to sodium benzoate.

The studies reported here were undertaken in an attempt to determine the degree of generality of the sodium benzoate effect. They were extensive, and only selected aspects of the results are reported. Focal points of the investigation were the following hypotheses:

1) Other substances will show the same kind of taste response variability as does sodium benzoate.

2) Variability will be greater for substances that are relatively unfamiliar to the test subjects than for substances that are familiar.

3) Certain features of a given person's responses will tend to be common among unfamiliar substances, but will be less so among familiar substances.

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Hypotheses 2 and 3 derive from the assumption that learning plays a major role in determining variability.

METHOD

Substances selected for investigation were: sodium chloride, sucrose, citric acid, and caffein, to represent familiar tastes; and sodium benzoate, potassium chloride, ammonium chloride, monosodium glutamate, and a "model solution," to represent unfamiliar tastes. The "model solution" was a mixture of the four familiar substances in proportions selected so that the intensities of *salt, sweet, sour,* and *bitter* should have been equal. All chemicals were C.P. grade or equivalent. Solutions were prepared with fresh, charcoal-filtered distilled water. A stock solution was prepared and diluted on a volume basis to assure accurate measurement of low percentages. Samples, 1 oz in quantity, were presented in whiskey shot glasses. All testing was done in special test booths in the Sensory Evaluation Laboratory at the Food & Container Institute.

Fig. 1 illustrates the test method. Instructions to the subjects were, essentially: "Taste the sample, re-tasting as often as you consider necessary, and rate the intensity of each of the flavor qualities, considering them in the order shown on the questionnaire." Subjects rinsed their mouths and waited 1 min between samples.

The test subjects were recruited from a pool of volunteers who regularly participate in food preference tests. The only selection criteria were willingness to test and availability for the entire series of tests. The panel was primarily male, the modal age was 22, and only a few had ever participated in taste experiments other than the rating of food preferences. Each subject participated in one or two training sessions to assure understanding of the task and of the test procedure.

A series of 3 solutions—"weak," "medium," and "strong"—was developed for each substance, and these series were equated for intensity among substances by an experimental procedure. The actual concentrations used are shown in Table 1. These 27 solutions, plus 3 distilled-water blanks, constituted the series for the flavor analysis experiment. A random order of the 30 samples was established for each of the 24 subjects, and the samples were tested, 5 at a session, in 6 sessions on different days. The order in which the four qualities appeared on the questionnaire was systematically varied. The entire experiment was replicated, using a new random order for each subject.

For analysis, the values 0-8 were assigned to the points of the scale, beginning at the "none" end. Analyses of variance were made on the data, assuming a Model I (Brownlee, 1960), where the sample is regarded as consisting of all groups in the population, and using replicate error as the error term. Separate analyses were done on each of the substances, including water.

Table 1. Percent concentration of solutions used in the flavor analysis.

Substance	Concentration level: Low	Medium	High
Sucrose	.453	1.980	8.600
Citric acid	.006	.022	.081
Sodium chloride	.041	.177	.770
Caffein	.014	.058	.241
Sodium benzoate	.120	.737	4.512
Potassium chloride	.043	.196	.897
Ammonium chloride	.015	.056	.210
Monosodium glutamate	.026	.226	2.017
"Model" solution	6.250	19.300	59.500
Constituents:			
Sucrose	.325	1.004	3.094
Sodium chloride	.035	.108	.333
Citric acid	.003	.010	.031
Caffein	.005	.015	.048

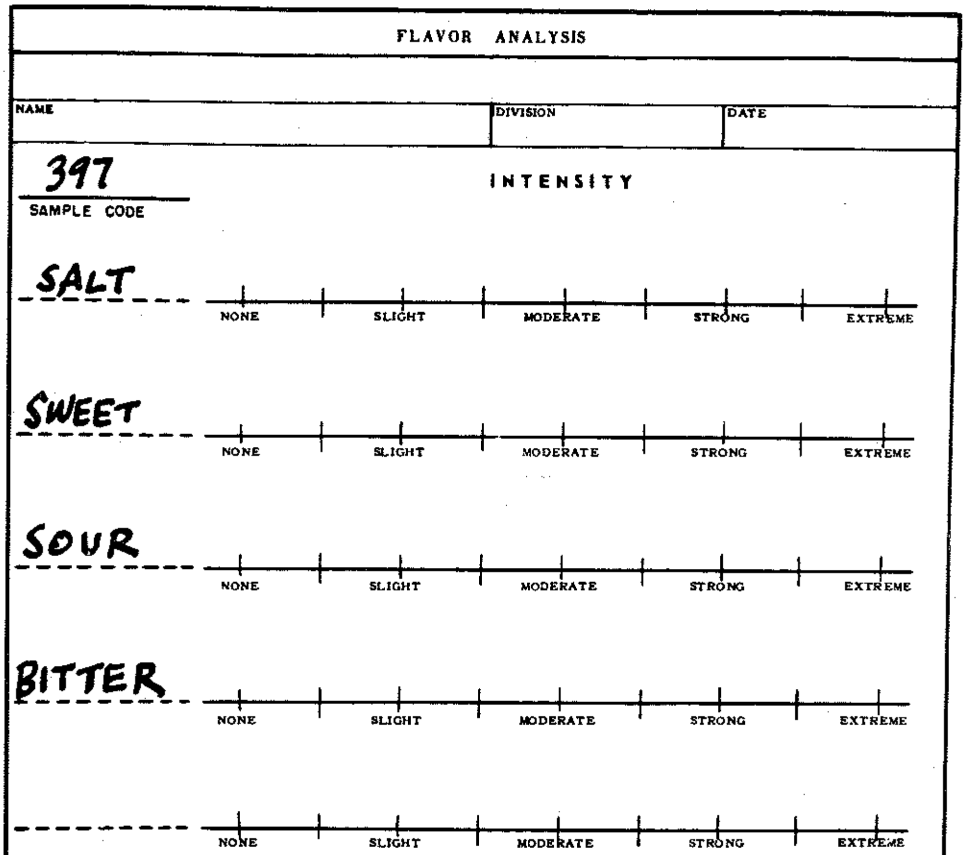
RESULTS

Figure 2 is an empirical display of the results. For each of the 9 substances (excluding water) the average intensity of each quality, based on 48 responses, is shown as a function of log concentration. In examining these charts it should be remembered that the over-all intensities were the same for all substances.

Sucrose and sodium chloride present clear pictures. The appropriate quality, *sweet* or *salt,* rises to a relatively high level, whereas the other three qualities stay near the zero line. With citric acid and caffein, the expected quality is clearly dominant, but some confusion is shown. *Bitter,* with citric acid, and *sour,* with caffein, also rise above the negligible level.

Inspection of the curves for sodium benzoate suggests that *sweet* is the dominant quality, but note that *bitter* rises to a higher level at the highest concentration, also that both *salt* and *sour* come into play. It is emphasized that these are averages for 24 people. The curves definitely show multiple qualities, but not whether this is because each subject perceived multiple qualities or because people just disagreed.

Potassium chloride is generally recognized as tasting *bitter* and *salt,* and ammonium chloride as *bitter* and *sour.* The charts agree, but also show that two qualities are not enough to describe



FLAVOR ANALYSIS

NAME	DIVISION	DATE

397
SAMPLE CODE

INTENSITY

SALT	NONE	SLIGHT	MODERATE	STRONG	EXTREME
SWEET	NONE	SLIGHT	MODERATE	STRONG	EXTREME
SOUR	NONE	SLIGHT	MODERATE	STRONG	EXTREME
BITTER	NONE	SLIGHT	MODERATE	STRONG	EXTREME
	NONE	SLIGHT	MODERATE	STRONG	EXTREME

Fig. 1. The flavor analysis questionnaire.

either of these substances; potassium chloride has an important component of *sour,* and ammonium chloride shows *salt.* Only *sweet* fails to appear.

Monosodium glutamate appears to cause even more disagreement than does sodium benzoate. *Sweet* stays relatively low, whereas the other three qualities all show significant intensity and are about equal.

The data on the "model solution" seem to demonstrate the failure of the objective in using this approach. *Sweet* is the dominant quality and increases progressively although *salt* emerges at the highest concentration. It is possible that the sucrose concentration was simply too high; on the other hand, there is some evidence in favor of the intrepretation that the dominant position of *sweet* in a mixture where all four qualities should have been about equal may have been a contrast phenomenon.

Table 2 presents an analysis of the replicate error. Each subject tested each solution twice, and this gave a component of variance that could be partialed out according to any of the other variables. The table shows the average for each level of each of the four independent variables. Note the wide range and rather flat distribution of error across subjects. The ratio was 7:1 between the largest and smallest variance. Some consideration was given to eliminating the highly variable subjects; however, analysis showed that the distribution did not depart significantly from normality.

Replicate error varied considerably as a function of substance. The smallest error (0.6) for water was less than one-third of the highest error (2.0) for monosodium glutamate. The low value for water is favorable evidence of stability of judgment. The four "familiar" substances (sugar, salt, caffein, and acid) plus water show the smallest error, and there is a definite cut-off between these and the "unfamiliar" substances.

Error varied regularly according to solution concentration, with error for "high" being over twice that for "low." Part of this difference is probably "real" in the sense that people can judge moderate and weak stimuli more accurately; however, it is also likely that part of the effect is an artifact of the scaling method. As actual intensity approaches zero, and ratings approach the lower end of the scale, the opportunity for variation in one direction is denied, so apparent variation is reduced.

Comparison of replicate error for the four qualities reveals clear differences. The relative order of precision of judgment is *sweet, salt, sour, bitter,* with the error for *bitter* nearly twice that for *sweet.* These differences were not due to scale effect, as were the concentration differences, since

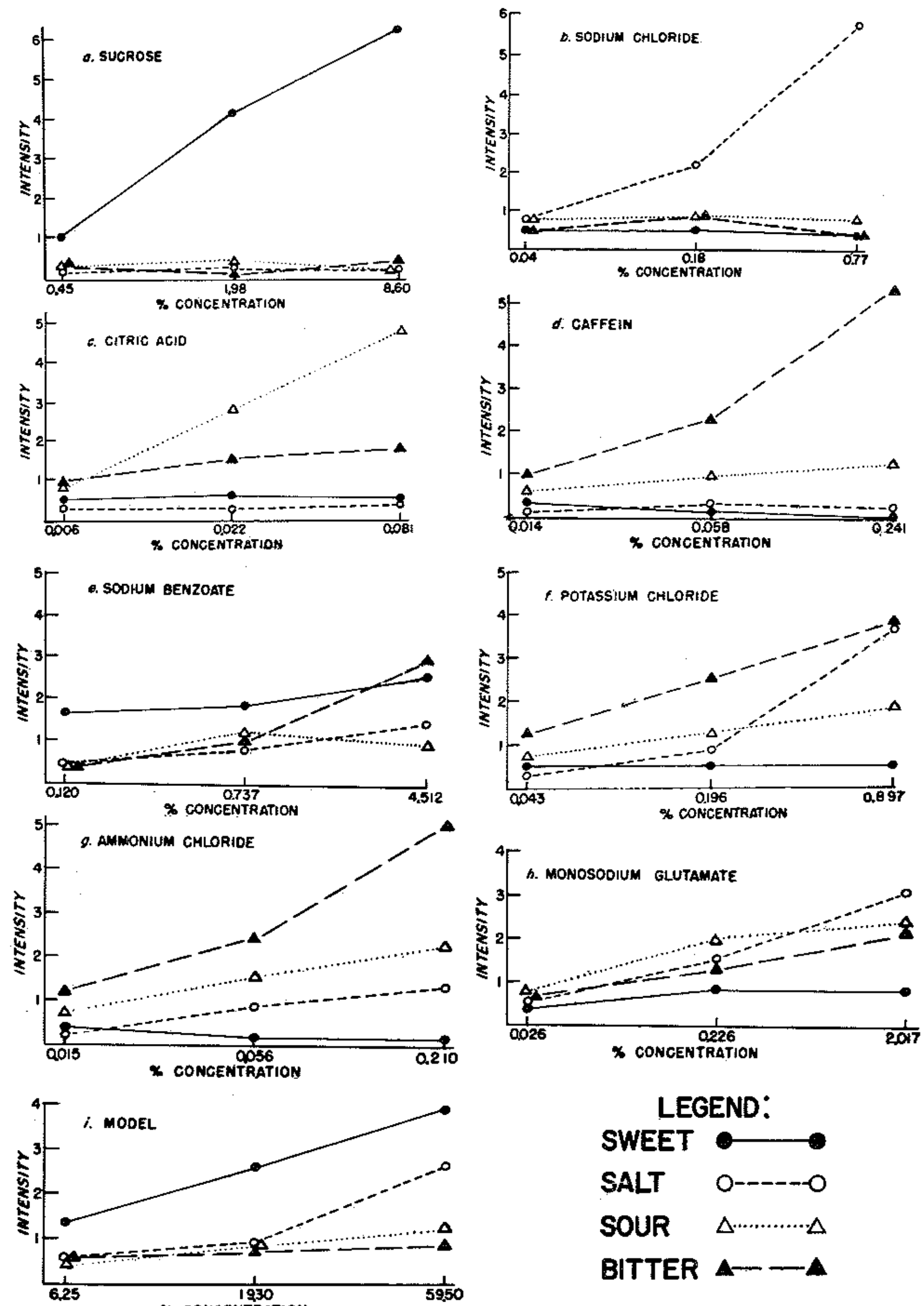


Fig. 2. Subjective intensity of four taste qualities as a function of log concentration for each of nine substances.

Table 2. Replicate error distributed according to the four independent variables.

		Subjects [a] Range	Number in range
Substance:			
Water	0.6		
Sucrose	0.8		
Sodium chloride	1.1	2.8–3.2	1
Caffein	1.3	2.3–2.7	3
Citric acid	1.4	1.8–2.2	4
Sodium benzoate	1.7	1.3–1.7	6
"Model" solution	1.7	0.8–1.2	5
Ammonium chloride	1.8	0.3–0.7	5
Potassium chloride	1.9		
Monosodium glutamate	2.0		

Quality:[b]		Concentration:[b]	
Sweet	1.1	Low	0.9
Salt	1.4	Medium	1.4
Sour	1.8	High	2.2
Bitter	1.9		

[a] Results for water included.
[b] Results for water not included.

all four qualities rated about the same when data were averaged across the entire experiment.

Table 3 presents information obtained in the analyses of variances done separately for each substance. Average variances for selected effects are shown. Most effects were highly significant, and it is the relative magnitudes that are of major interest.

Subject effect was small but significant with all substances, including water. This was expected, and is simply a demonstration that people have different ways of using scales. Again as expected, there was an important effect due to concentration (fortunately, it did not appear with water). By far the largest variances arose with quality. This demonstrates analytically what the charts show, namely, that there were reliable differences among the qualities used to describe each substance. Note the large variance for sucrose, where one quality was clearly dominant, and the relatively small variances for sodium benzoate and monosodium glutamate, where all four qualities were used to an important extent.

The quality-concentration interactions vary considerably, but have no major importance for our present purpose. This interaction arose from the fact that, as concentration changed, the relative importance of the qualities changed. In one sense, this is an artifact, since, at the "low" concentration, all qualities were of necessity near the zero level.

Subject-quality interaction has a particular significance with reference to the problem under investigation. It is a measure of the extent to which the subjects differed in the single qualities, or patterns of qualities, which they used to describe the substances. It shows that the multiple qualities, as displayed in the charts, occurred because people differed in the qualities used, and not because everybody used the same multiple qualities. A significant subject-quality interaction was found for every substance but water. It varied from a low of 1.7, for sucrose, to a high of 8.9, for monosodium glutamate. It is generally lower, indicating more agreement among subjects for the four familiar substances (the "pure" tastes) except for citric acid, which is exceeded only by sodium benzoate and monosodium glutamate.

The data so far presented have demonstrated the generality of the sodium benzoate effect. Different people responded in different ways to the other substances as well. Sodium benzoate is not unique; even such common things as sucrose

Table 3. Average variance attributable to various sources in the analyses of variance for ten substances.

Substance	Subject 23 [a]	Quality 3 [a]	Concentration 2 [a]	Quality-concentration 6 [a]	Subject-quality 69 [a]	Replicate error 288 [a]
Water	2.9	2.9	0.1 [b]	1.0 [b]	0.8 [b]	0.6
Sucrose	3.4	438.7	89.4	83.1	1.7	0.8
Sodium chloride	5.2	188.8	67.0	83.0	3.2	1.1
Citric acid	5.3	182.0	78.3	41.3	6.4	1.4
Caffein	4.6	229.4	66.6	57.3	2.8	1.3
Sodium benzoate	7.2	39.8	87.5	11.4	6.5	1.7
Potassium chloride	5.3	107.1	155.4	31.9	6.3	1.9
Ammonium chloride	8.5	182.2	116.1	36.5	4.8	1.8
Monosodium glutamate	5.9	31.1	106.7	11.6	8.9	2.0
"Model" solution	6.3	119.5	90.4	16.0	3.7	1.7

[a] Degrees of freedom.
[b] Except for these, all effects were significant at or below the 1% level.

and sodium chloride show some of the effect, and monosodium glutamate shows it to an even greater extent than sodium benzoate.

Do the results support the hypothesis that familiar substances will show less of such variation than the relatively unfamiliar? The two most appropriate indices of variability in this experiment were replicate error, a measure of intra-individual variation, and subject-quality interaction, a measure of differences among people in the qualities used. Table 4 ranks the familiar and unfamiliar substances from low to high on these two indices. On subject-quality interaction there is only one departure (citric acid) from the rule that familiar substances show less variability. On replicate error the data are in perfect agreement: the four familiar substances occupy the first four ranks. Thus the results tend to support Hypothesis 2, but with some qualification.

Table 4. Comparison of variability of response to familiar and unfamiliar substances.

	Subject-quality interaction rank	Replicate error rank [a]
Familiar substances:		
Sucrose	1	1
Sodium chloride	3	2
Citric acid	7	4
Caffein	2	3
Unfamiliar substances:		
"Model" solution	4	5.5
Monosodium glutamate	9	9
Potassium chloride	6	8
Ammonium chloride	5	7
Sodium benzoate	8	5.5

[a] Ranked from low to high.

The outcome on Hypothesis 3 is not so clear-cut. It is assumed that learning, along with physiology, plays an important role in determining how people respond to taste stimuli, and that a person tends to develop constant tendencies to respond in certain ways so that he is more likely to use some qualities than others. In other words, he has "preferred" and "non-preferred" qualities. With familiar substances, people have learned common ways of responding. Hence, personal idiosyncracies should be less important; however, with unfamiliar substances, these individual tendencies should appear in greater strength.

An analysis was made to test this hypothesis. Each subject's average rating for each quality, across all concentration levels of the nine substances (excluding water), was obtained, then "corrected" by subtracting the subjects' own over-all average (to adjust for his possible tendency to rate high or low) and the over-all average level for the quality (to adjust for the fact that the substances, as a group, were actually stronger in some qualities than others). Comparisons of the residuals permitted identification of "preferred" qualities (those used more often or rated higher) and "non-preferred" qualities (those used less often or rated lower). Most subjects showed such tendencies: 14 had one "preferred" quality, 15 had one "non-preferred" quality, 11 had both.

The pattern of qualities used by each subject to describe each substance was determined by inspection. Table 5 displays the patterns for sucrose and caffein, two of the least variable substances, and for sodium benzoate and monosodium glutamate, the two most variable substances. With the familiar substances, the patterns were regular and could have been predicted from the average curves. Most people used the "appropriate" quality although they might vary in the "other"

Table 5. Combinations of taste qualities used by test subjects to describe each of four substances.

Substance	Combination	No. of subjects using
Sucrose:	Sweet	19
	Sweet-sour	2
	Other	3
Sodium chloride:	Salt	11
	Salt-sour-bitter	3
	Salt-sweet-sour	4
	Salt-bitter	3
	Salt-sour	2
	Salt-sweet	1
Sodium benzoate:	Bitter-sweet	6
	Sweet-sour	3
	Sweet-salt-sour-bitter	3
	Bitter	2
	Sweet	2
	Sweet-salt-bitter	2
	Other	6
Monosodium glutamate:	Salt-sour-bitter	5
	Sweet-salt-sour-bitter	6
	Sour	3
	Bitter	3
	Salt-sour	2
	Other	5
Citric acid:	Sour	5
	Bitter	2
	Sour-bitter	10
	Sour-salt	3
	Sour-sweet	2
	Other	2

qualities mentioned. It was clear that the qualities, and patterns of qualities, used here were determined primarily by the substance. But for the five unfamiliar substances the patterns were many and various, like the two examples shown.

Individual patterns on the five unfamiliar substances were examined to determine whether they were consistent with the subjects' "preferred" and "non-preferred" qualities. Of 120 cases (24 *S*'s × 5 substances) the consistent cases outnumbered the inconsistent cases about 2 to 1; however, in about one-third of the cases no determination could be made. It was concluded that constant tendencies, as here defined, are not very good predictors of responses to particular unfamiliar substances; although there is some relationship.

Further evidence on this point was sought by a correlation method. If most people respond to familiar substances in the same way because the responses are determined by the nature of the substance and the function of the taste receptors, ratings should not be correlated between substances; on the other hand, if responses to unfamiliar substances are determined to a large extent by personal factors, not necessarily related to the substance or taste receptor function, these ratings should tend to correlate positively.

The complete matrix of inter-substance correlations was derived for each quality. Significant positive correlations occurred about twice as often among the unfamiliar substances as among the familiar substances, which would tend to support the hypothesis; however, familiar substances were positively correlated with the unfamiliar substances about as often, something that would not be predicted by the hypothesis. Thus, the analysis provided only weak support for the "constant tendencies" hypothesis.

CONCLUSIONS

The generality of the sodium benzoate effect was proven. For people to use different qualities to describe the same substance appears to be the rule rather than the exception. Familiar substances tend to show less of this variability than do substances that represent new taste experiences. Although individual constant tendencies to respond with certain qualities could be identified, they did not appear to be important determiners of the patterns of response even to unfamiliar substances. The hypothesis that learning is an important cause of interpersonal variability was weakly supported, but not proven.

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